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2.7 Scientific goals of the Cooperative Multiscale Experiment (CME)

William Cotton

Mesoscale Convective Systems form the focus of CME. Recent developments in global climate models, the urgent need to improve the representation of the physics of convection, radiation, the boundary layer, and orography, and the surge of interest in coupling hydrologic, chemistry, and atmospheric models of various scales, have emphasized the need for a broad interdisciplinary and multi-scale approach to understanding and predicting MCSs and their interactions with processes at other scales. The role of mesoscale systems in the large-scale atmospheric circulation, the representation of organized convection and other mesoscale flux sources in terms of bulk properties, and the mutually consistent treatment of water vapor, clouds, radiation, and precipitation, are all key scientific issues concerning which CME will seek to increase understanding. The manner in which convective, mesoscale, and larger scale processes interact to produce and organize MCSs, the moisture cycling properties of MCSs, and the use of coupled cloud/mesoscale models to better understand these processes, are also major objectives of CME. Particular emphasis will be placed on the multi-scale role of MCSs in the hydrological cycle and in the production and transport of chemical trace constituents. The scientific goals of the CME consist of the following:

- Understand how the large and small scales of motion influence the location, structure, intensity, and life cycles of MCSs.
- Understand processes and conditions that determine the relative roles of balanced (slow manifold) and unbalanced (fast manifold) circulations in the dynamics of MCSs throughout their life cycles.
- Assess the predictability of MCSs and improve the quantitative forecasting of precipitation and severe weather events.
- Quantify the upscale feedback of MCSs to the large-scale environment and determine interrelationships between MCS occurrence and variations in the large-scale flow and surface forcing.
- Provide a data base for initialization and verification of coupled regional, mesoscale/hydrologic, mesoscale/chemistry, and prototype mesoscale/cloud-resolving models for prediction of severe weather, ceilings, and visibility.
- Provide a data base for initialization and validation of cloud-resolving models, and for assisting in the fabrication, calibration, and testing of cloud and MCS parameterization schemes.
- Provide a data base for validation of four dimensional data assimilation schemes and algorithms for retrieving cloud and state parameters from remote sensing instrumentation

The importance of studying the scale-interactive processes that govern the frequency, location, evolution, and feedback effects of MCSs is clear in light of the role that they play in producing severe weather and their impact upon the earth's global-scale circulation, climate, hydrological cycle, and chemical and electrical balances (through their vertical and horizontal transports of water substance, heat, momentum, and chemical trace species, and because of their radiative and electrification effects). A multiscale experiment is required because MCSs range in scale from 100 to 400 km, yet they alter the atmosphere on scales of 1000's of kilometers, and they are composed of thunderstorm elements on scales of <10 km which produce a significant fraction of the fluxes, heating, rainfall, and severe weather. Furthermore, since MCSs have lifetimes of the order of 10 hours or more, to capture their entire lifecycle requires a network of the order of 3-4 $\times 10^3$ km in scale. Finally, the genesis of MCSs is thought to be the result of processes occurring over a wide range of scales, from that of jet streaks (L ~2500 km) to that of mesoscale instabilities and surface physiographic variations (L ~10's to 100's of kilometers). Moreover, such a multiscale experiment is necessary to initialize and validate regional and mesoscale models and to assist in the development and testing of MCS parameterization schemes for use in global-scale models.

The CME scientific steering committee has chosen the central United States as the location for study of mesoscale convective systems. Although from a climatic and hydrological point of view, the greatest impact of mesoscale convective systems is at tropical latitudes, especially over the oceans, these regions are not data-rich. Furthermore, expensive, logistically difficult experiments such as TOGA COARE, which provide only snapshot coverage of MCSs and very spotty larger scale meteorological coverage as well, are required in such regions. Fortunately, there is also a high frequency of MCS activity over the central United States in the spring and summer months, and research has shown that many of these mid-latitude systems are similar to their tropical cousins. Thus, models and cloud parameterization schemes developed and tested with high density data in the mid-latitude environment (which ranges from highly baroclinic to nearly tropical) can be more easily tested, modified, and adapted to the tropical environment with sparse data. Of course, the biggest advantage of performing a multiscale experiment in this region is the availability of frequent, high density operational measurement systems ranging from standard rawinsonde soundings, to automated surface stations, a network of wind profilers, modern WSR-88D doppler radars, and ACARS wind data. Thus an opportunity exists to carry out a true multiscale experiment by supplementing these standard observational systems with special research-grade systems at relatively modest cost. Furthermore, the ARM program provides an additional source of regular radiation measurements plus supplemental wind profiler and surface measurements that further reduces the cost of carrying out a multiscale experiment. Finally, as already discussed, the other programs which have an expressed interest in cooperating in a multiscale experiment to study MCSs (USWRP, GCIP, GCSS, GVaP, ARM, and AWP) all have plans to concentrate their separate activities within this region.

A cooperative experiment is needed, because even though the costs of implementing a multiscale experiment in the central U.S. is reduced by the availability of routine measurement systems, the total additional observing systems needed to provide the necessary multiscale measurements is still quite expensive. The other programs (decribed above) share a common interest in furthering our understanding of MCSs and would benefit from a major multiscale experiment, yet no single one of these programs is likely to muster the resources needed to carry this out. A cooperative program is the wisest investment of resources if multiscale, interdisciplinary processes are the focus, so it is important that these programs join forces to implement such a multiscale experiment.

The multi-scale experiment is proposed to consist of meso-α scale arrays (Figs 6 and 9), meso-β scale arrays (Figs. 6, 7, 8, and 10), a meso-γ scale array (likely located at or near the CART/ARM site or within the Chickasha Watershed study area (Fig. 4)), and mobile platforms like aircraft. Ideally, running the field experiment from mid-April to mid-August in 1995 would allow sampling both spring storms residing in a rather baroclinic environment and mid-summer storms which reside in a more barotropic, tropical-like environment. Three plans are presently being considered, in order of decreasing breadth and cost: (a) a four-month field program, which would cost \$5-6M in new monies; (b) two 6-week programs designed to sample the broad range of MCSs while realizing an added risk of sampling few storms of a given type, which would cost \$4M; and (c) a single 2-month program running from about 20 May to 7 July, which is a further compromise in design in order to reduce the direct costs of running the experiment to its minimum (\$2M). Details appear in the CME Draft Science Plan.

The overall organization of the CME consists of a scientific steering committee, an experiment implementation committee, a project management committee, and a science team. The scientific steering committee should consist of leading scientists participating in the various component programs who can provide scientific leadership in the experiment design, implementation, operation, data archival, and procurement of facilities by serving as principal investigators on proposals and requests for facilities. An experiment implementation committee, to be formed by the scientific steering committee, will finalize details in the experiment design, determine field operational procedures, data management procedures, and data archiving. A project management committee, to consist of one or more representatives from each of the cooperative programs and agencies, will be formed to provide direct interfaces with the cooperative programs and national and international agencies. A field project support office will provide logistical suport in carrying out the various recommendations provided by the working committees, including processing of documents, interfacing with program and agency representatives, organizing meetings, providing data management, and guidance and participation in field program implementation. Finally, a science team will consist essentially of all participating scientists in the cooperative field program.

3. Colloquium presentations

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3.1 Grand challenge scientific questions in coupled modeling

Steven Koch

The "kickoff presentation" by the colloquium organizer was designed to set the background for the colloquium. Differences between past convective field experiments and the present opportunity for a truly multiscale field experiment were highlighted. This opportunity has arisen in part from the modernization of the nation's weather observing capabilities and also from the recent or planned establishment of special observing systems over the central U.S. by several new programs (ARM, GVaP, etc.). Most convective field experiments in the past (e.g., SESAME, CCOPE, CINDE) have attempted to resolve only the immediate scales of moist convection using network arrays that spanned two or three atmospheric scales at most. Furthermore, these scales have been defined more on practical considerations (cost, manpower, etc.) than on a clear understanding of their theoretical significance. Unfortunately, this has precluded a description of the entire life cycle of MCSs and their interaction with larger scale systems, the land surface, and trace species. Fortunately, the following factors now make it possible to attempt to simulate scale contraction processes from the synoptic scale down to the cloud scale, as well as interactions between complex meteorological, land surface, precipitation, chemical, and hydrologic processes with coupled, multiscale models:

- The availability of new technology to sample meteorological fields at high temporal and spatial resolution over a *broad* region made possible by the weather observing modernization program
- Increased computer power and improved numerical approaches to run limited area models with nonhydrostatic precipitation physics so as to explicitly resolve MCS processes
- Four dimensional assimilation of non-conventional data to provide dynamically consistent datasets for diagnostic analysis of nonlinear scale-interactive dynamics